NOTE ON THE LOW ENERGY SCATTERING OF PROTONS BY PROTONS

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ABSTRACT. The scattering of protons by protons has been investigated in the energy region .2 to .3 Mev by Ragan, Kanne and Taschek.[1] This note derives the necessary theoretical calculations for the analysis of the experimental data Phase shifts for the Gauss, Meson, Exponential, Morse and Square potential wells are determined Curves of the Mott ratio, including the effect of S-wave scattering for all potential wells, are given.

G. L. Ragan, W. R. Kanne and R. F. Taschek [1] have investigated the scattering of protons by protons in the energy region from 200 to 300 kev, experimentaliy. For purpose of comparison with theoretical results, a detailed investigation of this energy region has been made, theoretically, at energy intervais of 10 kev and for all the potential functions utilized thus far in the study of the problem. The analysis of proton scattering data [1,2,3] has shown that experimental data may be fitted almost exactly to theory by the assumption of a pure s-scattering alone; this is especially true in the region under consideration. It has been shown that the experimental data on proton-proton scattering can be fitted by a square well[2] of depth 10.5 Mev and range e^2/mc^2 and a Gaussian[2] type potential[3] well Ae^{-r^2} with $A=51.44\ mc^2$ and $=21.50$ Mmc^2 cut off at 3 e^2/mc^2; a Meson potential well[4] $Ce^{-r/a}/(r/a)$ with $C=89.65\ mc^2$ and $a=0.42\ e^2/mc^2$; an exponential potential well[5] $Be^{-2r/b}$ with $B=137.6\ mc^2$, $b=0.193\ (Mmc^2)^{-\frac{1}{2}}$; a Morse potential well[6] $D(e^{-4r/a} - 2e^{-2r/a})$, with $D=119.36\ mc^2$, $a=e^2/2mc^2$. The agreement between theoretical and experimental results using these potentials confirms the existence of only an s-wave anomaly in the scattering and the equality of neutron-proton and proton-proton interactions.

The present theoretical calculations extend the region of investigation so as to cover the new experimental data. The method of calculation consists in solving numerically the differential equation $d^2F/dr^2+(E-V(r))\ F=0$ using the units and numerical values of the constants given above for each potential, cutting off the solutions at 3 e^2/mc^2 and joining to Coulomb functions. The Coulomb functions needed for these calculations were computed from series expansions.[7] Curves giving the variation of phase shift with energy over this region are given in Figure I for all potentials. The curve represented by crosses gives the variation of K_0 with energy for the Meson potential; the elliptical circles represent the square well potential; the circles represent the exponential and the dots and squares the Gauss and Morse potentials respectively. Figure II

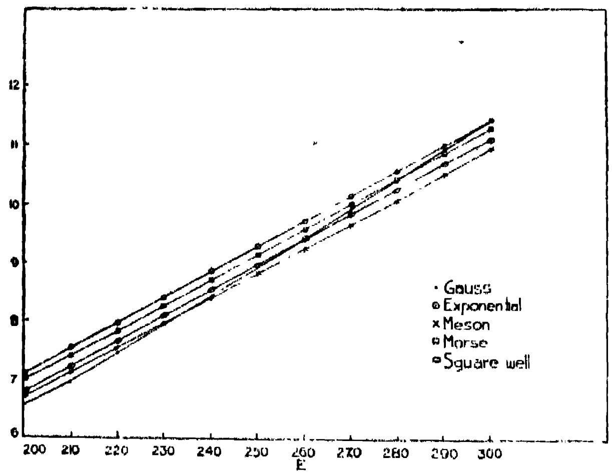

FIG. I
Variation of Phase shift with energy

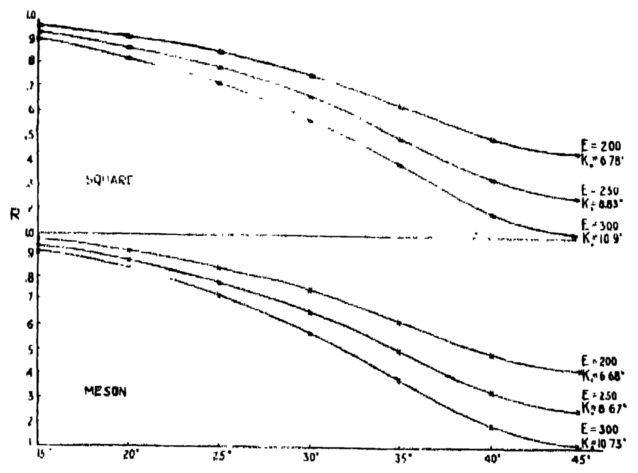

FIG. II
Mott ratio as a function of the angle of scattering

shows curves of the Mott ratio (R) plotted as ordinates with the scattering angle Θ as abscissae for the square well and the meson potentials. These curves are typical of the curves for R as a function of Θ for all potentials. The actual numerical values for the calculated phase shifts for all potentials are tabulated in Table I.

TABLE I

Theoretical Phase Shifts

—	Square	Gauss	Exponential	Meson	Morse
E_{kev}	K_0	K_0	K_0	K_0	K_0
200	6.78°	6.59°	7.05°	6.68°	6.97°
210	7.18°	6.93°	7.45°	7.08°	7.35°
220	7.60°	7.15°	7.87°	7.47°	7.77°
230	8.02°	7.90°	8.28°	7.87°	8.18°
240	8.43°	8.37°	8.68°	8.27°	8.59°
250	8.83°	8.82°	9.11°	8.67°	9.02°
260	9.25°	9.30°	9.53°	9.06°	9.43°
270	9.70°	9.78°	9.96°	9.48°	9.85°
280	10.08°	10.28°	10.38°	9.88°	10.28°
290	10.52°	10.78°	10.82°	10.31°	10.72°
300	10.90°	11.30°	11.25°	10.73°	11.15°

Figure III gives typical curves of the Mott ratio R as a function of energy

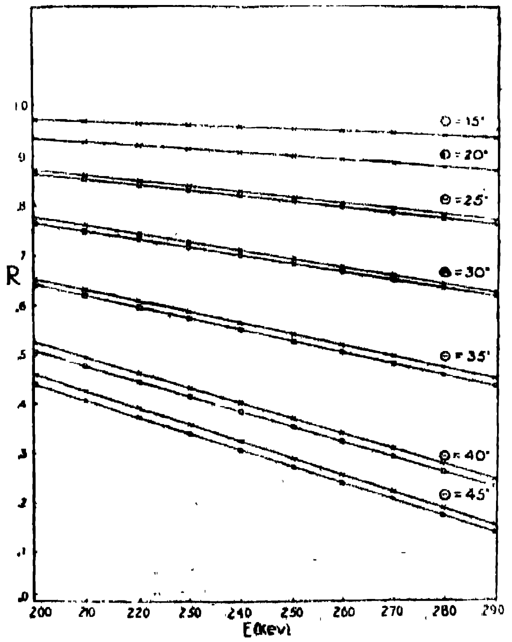

FIG. III

Mott ratio as a function of the energy

in Kev for the Meson potential (crosses) and the Morse type potential (squares). Figure IV shows the quantity $4cMR/sE^2$ plotted against energy for the

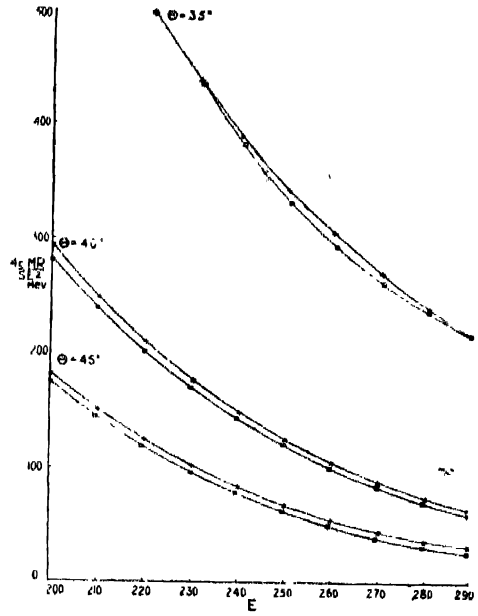

FIG. IV
The quantity $4cMR/sE^2$ as a function of energy

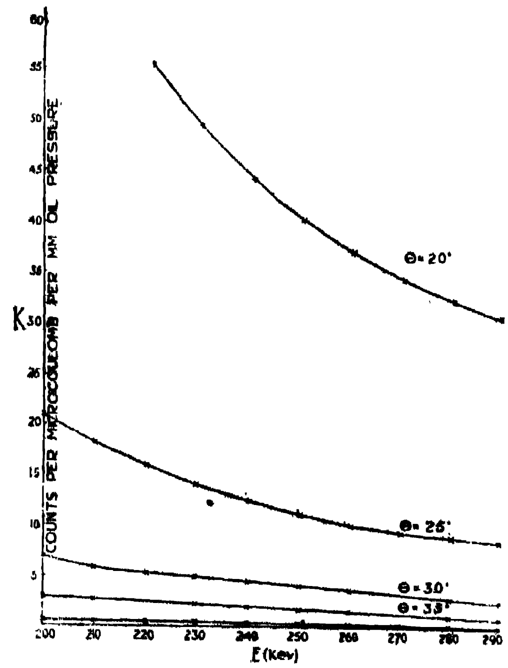

FIG. V
Counts per microcoulomb per millimetre oil pressure as a function of energy

scattering angles $\Theta = 35°$, $40°$ and $45°$. Figure V are curves of the proton counts per microcoulomb per millimetre oil pressure against energy as calculated for the Meson potential.

The data given by these calculations may be used for direct comparison with the experimental data and such a comparison may lead to the choice of a potential well more closely satisfying the conditions in nuclear problems.

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